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Pilot acoustic tracking study on adult spiny lobster (Palinurus mauritanicus) and spider crab (Maja squinado) within an artificial reef

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Pilot acoustic tracking study on adult spiny lobster (*Palinurus mauritanicus*) and spider crab (*Maja squinado*) within an artificial reef

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Abstract The behavior of crustacean decapods is poorly characterized in artificial reef areas, being of relevance for population management and conservation studies based on capture and release. Acoustic tags were used to study the behavior of 3 adult spiny lobsters (*Palinurus mauritanicus*) and 3 spider crabs (*Maja squinado*), evaluating the use of artificial reef areas as suitable sites for re-stocking of overfished decapods. For this purpose, animals were released in a western Mediterranean artificial reef located at 20 m depth, close to a cabled sea-floor observatory (OBSEA). That cabled platform recorded simultaneously temperature, salinity, current direction plus speed, and light intensity close to these structures. The study lasted 64 days and was carried out during summer. Spiny lobster lingered in the reef area, while of the spider crab only remained between 21 and 45 hours. These behavioral differences suggested that artificial reefs might be a good area to deploy adult lobsters for re-stocking purposes. The movements displayed by the lobsters during this experiment were not influenced by any of the measured environmental factors, while spider crab movements took place against current major direction, when speed current was intense.

Key words: ultrasonic transmitters; crustaceans; artificial reef; restocking; environmental factors; cabled observatory

Introduction

In the western Mediterranean, lobsters and crabs stocks are threatened due to their past and present severe overfishing (Sardà & Martin, 1986). For example, in the Western Mediterranean Catalan official landings of the last 10 years show how captures of benthic crustacean have significantly decreased of a 5 % ($p<0.0013$**; $R^2=0.6227$). These crustaceans are especially vulnerable because of their low mobility or ability to escape from divers and/or gear devices, and also by its high mortality in the early stages of development (Abad, 2003; Goñi & Latrouite, 2005; Stevcic, 1967, 1977). The restocking in sensitive sites is a critical tool to preserve biodiversity, living resources, and for ecosystem conservation and can also be used as an effective tool for fisheries management (Bell et al., 2006). However, restocking is not an easy task and it would be desirable any essential knowledge on the behavior of individuals in relation to their movement patterns and *in situ* permanence within a specific area.

To our best knowledge no telemetric studies have been performed on the spiny lobster *Palinurus mauritanicus* Gruvel, 1911 and the spider crab *Maja squinado* (Herbst, 1788), although some data on the biology of these species is available (Bussani & Zuder, 1977; Diop & Kojemiakine, 1990; Durán et al., 2012; Goñi & Latrouite, 2005; Guerao et al., 2008; Guerao & Rotllant, 2010; Hunter, 1999; Rotllant et al., 2014; Stevcic, 1967, 1968, 1973, 1977). In contrast, the biology and behavior of other species within the same genus were approached by telemetry in Southern Europe, such as: *Palinurus elephas* (Fabricius, 1787) (Giacalone et al., 2006; Hunter, 1999) and *Maja brachydactyla* Balss, 1922 (Freire, 1999; Gonzalez-Gurriaran & Freire, 1994; Gonzalez-Gurriaran et al., 2002; Hines et al., 1995). Although some studies were initially referred to *M. squinado* they corresponded to *M. brachydactyla*, since animals were captured in

the Atlantic and only recently populations has been ascribed to a different species (Guerao et al., 2011; Sotelo et al., 2009).

Previous studies for *P. elephas* showed a shelter-life habit (Giacalone et al. 2006; Goñi & Latrouite, 2005) and short range displacements (i.e. > 5 km), although winter offshore migration was suggested by Hunter (1999). Herrnkind (1980) conversely, defined three spatial categories of movement in spiny lobster: (1) homing (the ability for a lobster to return to a specific shelter after foraging), (2) nomadic (undirected, long range displacements away from current shelters), and (3) migratory (vertical or horizontal seasonal displacements in and away from current shelters). Although the variations of temperature, salinity, photoperiod, light levels, oxygen, and so on, may be coincident with lobster movements, Herrnkind (1980) failed in identifying key eliciting stimuli. Recently, Bertelsen (2013) probed that the percentage of lunar illumination triggers the movement of large males of *Panulirus argus* (Latraille, 1802). The spiny lobster *Panulirus cygnus* George, 1962 seems to displace according to current directions (Jernakoff & Phillips (1988). Counter-current migration apparently favour larval dispersal in *Palinurus delagoae* Barnard, 1926 (Groeneveld, 2002), *Palinurus gilchristi* Stebbing, 1900 (Groeneveld & Branch, 2002) and *Jasus verreauxi* (H. Milne-Edwards, 1851) (Booth, 1997). In a later mark-recapture study the Rock lobster, *Jasus edwardsii* (Hutton, 1875) chiefly remained within 5 km (Linnane & Dimmlich, 2005). MacArthur et al. (2008) using acoustic telemetry also observed that sub-adults of the lobster *P. cygnus* in the absence of fishing pressure do not displace. *J. edwardsii* adults move seasonally to close deep waters however no correlation was found between temperature, wave surge or photoperiod and their movements (MacDiarmid, 1991). In the Mediterranean, the slipper lobsters *Scyllarides latus* (Latraille, 1802) migrate into deeper water as the sea temperature rises in summer, but

tagged individuals were seen to return to the reef over a 3 year period (Spanier et al., 1988). In the South African coast, it has been demonstrated by acoustic tracking that males of *Jasus lalandii* (H. Milne-Edwards, 1851) displayed classical nomadic behaviour (Atkinson et al., 2005).

Spider crabs also present seasonal migrations. Stevcic (1973) suggested a reproductive migration pattern since captures of *M. squinado* adult males in the Adriatic Sea reach a maximum in April, while females present it in May. In a mark-recapture experiment Bussani & Zuder (1977) released mainly females from the Yugoslavian coast to Trieste and observed that at least 40% of the animals remained in the release area during 120 days, nevertheless in the following two years 3% of the released crabs were found far from the release area. In the sibling species *M. brachydactyla* mark-recapture studies demonstrated that crabs moved as far as 200 km (Camus, 1983; Latrouite & Le foll, 1989; Le Foll, 1993). Later, an ultrasonic telemetry study showed that adult crabs migrated in autumn to deep-water when temperature and salinity in shallow areas dropped while juveniles remained in coastal areas (Gonzalez-Gurriaran & Freire, 1994). Other behavioural studies with acoustic tagging that blue crab *Callinectes sapidus* M.J. Ratthbun, 1896 males move to deeper waters to avoid ice in winter while female migrate long distances to the lower bay to incubate the eggs (Davis et al., 2005b; Hines et al., 1995). The portunids crabs *Arenaeus crirabius* (Lamarck, 1818) and *Callinectes ornatus* Ordway 1863 have erratic spurts and showed movement away from their area of release of 18 and 4 km, respectively (Guerra-Castro et al., 2007). *Cancer pagurus* Linnaeus, 1758 males were captured 1 to 8 km from their point of release in a 7 years study whereas females moved longer distances, up to 21 km, in autumn with a net southerly direction (Ungfors et al., 2007). In the same study, the acoustic tracking of males showed both directed and irregular movements over thousands meters. Acoustic

telemetry was also used to check the release of the Atlantic rock crab *Cancer irroratus* Say, 1817 in an estuarine mussel aquaculture site in Canada. Resident males migrated upstream in winter and returned to the estuary in spring while few translocated crabs returned to the estuary (Comeau et al., 2012). *Scylla serrata* (Estampador, 1949) is a mangrove resident crab; mark-recapture experiments demonstrated that 93% of juveniles recovered remain in the release area, adult females moved longer distances than males, and only mature females migrated into the sea to spawn (Hill, 1975; Hyland et al., 1984; Le Vay et al., 2007). Juveniles of the blue also stay in the release area (Davis et al., 2004; Davis et al., 2005b).

Artificial reefs appear to be a tool of coastal management that helps to share coastal zone resources among users (Jensen et al., 2000; Nonaka et al., 2000). These structures have been deployed in many muddy coastal areas in Europe under fishing impact with two main goals: avoid trawling and to concentrate biomasses; thus, increasing fishing efficiency, but may also provide new habitat for juveniles collected from elsewhere in smaller artificial habitats (Eggleston et al., 1990). Artificial reefs were implemented in 1992 off the Vilanova i la Geltrú (the Spanish western Mediterranean), where trawling was already prohibited (Revenga et al., 2000), in an area that today hosts the cabled coastal Seafloor Observatory (OBSEA; Aguzzi et al., 2011). That platform is used for the continuous multiparametric ecosystem survey hosting instruments for long-term monitoring of different oceanographic parameters. The coupling of that platform with the existing artificial reefs make the OBSEA site a suitable zone for interdisciplinary studies on individual and population behaviour (Aguzzi et al., 2013; Condal et al., 2013).

We performed a pilot study with the objective of compare the behaviour of the spiny lobster and the spider crab in artificial reef areas by releasing animals where the

158 multiparametric OBSEA platform is deployed. Acoustic detections on the positioning of
159 animals were compared with concomitant measurements of water mass properties as
160 provided by the OBSEA in a first attempt to evaluate which factors may influence
161 individual behaviour, being hence of relevance of tagging-release studies at the base of
162 restocking policies .
163

164 **Materials and methods**

165

166 Animals' origin and artificial reef location and description
167 Adults *P. mauritanicus* (3 males; 72±2 mm carapace length, CL) were caught by a
168 trawling fishing boat from the Vilanova i la Geltrú harbor (Barcelona, Spain; Fig. 1) and
169 kept within a in 200 L tank connected to a recirculation unit providing constant
170 conditions of salinity (36‰) and temperature (18ºC) for 24 h without feeding until the
171 next-day release. Adult *M. squinado* (3 males; 155±10 mm CL) were captured off the
172 North of Corsica (France) and transported to the facilities of the IRTA (Sant Carles de
173 la Ràpita, Spain), where they were hosted in 2000 L tanks with recirculating water
174 system (IRTAmar@TM) during three months at condition equals to those of *Palinurus*.
175 Spider crabs were transported to Vilanova i la Geltrú the same day of releasing.
176 Animals were fed with mussels and fresh crab (*Liocarcinus depurator* Stimpson, 1871
177 and *Macropipus tuberculatus* Prestandrea, 1833) until their liberation in the artificial
178 reefs. The day before realizing, animals were unfed.
179 The artificial reef area is composed by a mixture of 20 protection and production
180 modules located 4 km off of Vilanova i la Gertru at a depth of 20 m. In particularly, the
181 4 production modules close to the coastal Seafloor Observatory (OBSEA;

182 www.obsea.es) were used for the study (Fig. 2). Each production module is formed by a
183 big (1x1x2 m) and heavy (5 t) cement structure that stand proud of the seabed and have
184 holes and sheltered spaces in them to encourage epibiotic colonization and promote fish
185 recruitment (Revenga et al., 2000). Summer period (July to September) was chosen for
186 the experiment since anticyclonic conditions ensured the maintenance and monitoring of
187 equipment with reduced risks of storms.
188
189 Tagging methodology
190 VEMCO Ltd (Halifax, Canada) ultrasonic telemetry equipment was used to monitor the
191 movements of animals. Four hydrophones (H) (model: VR2W Coded Acoustic Receiver
192 with Bluetooth) were situated in the artificial reef (AR) as shown in Figure 2. Three
193 hydrophones were placed inside the reef modules as follows: AR1-OBSEA (H37: 41º
194 10.914'N, 1º 45.141'E), AR2 (H38: 41º 10.882'N; 1º 45.106'E) and AR3 (H39: 41º
195 10.867'N, 1º 45.188'E). A fourth hydrophone was placed in the middle of the perimeter
196 delimited by AR1, AR2 and AR3 (H40: 41º 10.894'N, 1º 45.1603'E). Hydrophones
197 were time-synchronized prior the deployment according to the VUE manufacturer's
198 software.
199 The transmitters, model "V6" (6 mm of diameter and a weight of 0.5 g in water),
200 operates at 180 kHz in a range of up to 200 m salt water, and were sealed and glued on
201 the carapace of the animals with quick epoxy adhesive. To assure that the transmitter
202 was not lost, animals were tagged 24-h before their release and the day of release the
203 magnetic bar was removed to activate the transmitter. During this period animals were
204 kept in the tank with the magnet attached to the transmitter as showed for the transmitter
205 glue to the spider crab carapace. When the animals were released the magnet was taken

206 out and the signal and recording started as showed for the transmitter glue to the
207 cephalothorax of the lobster hanging in the artificial reef module.
208 Animals were released inside the artificial reefs by SCUBA divers- on the 18th of
209 July 2011. Only adult males (carapace length of 72±2 and 155±10 mm for lobsters and
210 crabs, respectively) were chosen for this study, to avoid potential interferences with
211 reproductive cycle. One lobster and one spider crab were released in each artificial reef
212 (AR1, AR2 and AR3). Experiment ended the 20th of September 2011 when
213 hydrophones were recovered.
214 Transmitters were programmed to emit data every 30 seconds in order to extend
215 the battery life of the transmitter during the 64 days that lasted the study. All
216 transmitters sent data in the same way, so if two or more transmitters were working
217 together there might be some signal collisions or false detections. However, after each
218 transmission, the transmitters waited a random time until the next transmission, greatly
219 reducing potential false detections. If the transmitter was in the reception area of the
220 hydrophone, the identification (ID) of the transmitter was stored along with a time-
221 stamp and the serial number of the hydrophone. Later, crossing the data between
222 hydrophones allowed checking the range of transmitters or evaluating the interferences
223 of the reef's walls.
224
225 Behavioral data collection
226 ID data were time-stamped and stored in the memory of each hydrophone. VUE
227 software allowed the data downloading to tabulated files. The estimation of trajectories
228 was performed analyzing the number of detections of each hydrophone per hour. When
229 the animal left a sector covered by a certain hydrophone, displacing to the nearby one,
230 the number of detections of the former decreased and increased in the latter.

231 In order to estimate the percentage of activity of a species (i.e. the movements
232 realized by each specimen), a reference value of zero activity is required. Activity
233 indicates the animals' displacements per unit of time as indicated by pin detections
234 within the hydrophone network. That network infrastructure is able to identify animal
235 presence as far as 200 m of distance form acoustic detecting sources. Drops in
236 detections at one source indicate the movement of the animal away from it. Thus, the
237 implemented algorithm considered a maximum in activity when the number of
238 detections was minimal (i.e. the animal was moving, hence leaving the zone and
239 transmissions were lost by a hydrophone). With this reference value, the numbers of
240 detections were scaled to percentages, and the activity between individuals and species
241 could be compared.
242
243 Environmental data collection
244 The CTD – SeaBird SBE-37SMP- and ADPC – Nortek AWAC current profiler – are
245 the instruments connected to the OBSEA infrastructure that provides the following
246 environmental data: temperature, pressure, salinity, current speed and current direction.
247 These data were processed by LabVIEW all the variables were averaged per hours.
248 Light intensity data were gathered from an automatic meteorological station
249 (http://www.meteo.cat/xema/AppJava/SeleccioPerComarca.do) part of the the Servei
250 Meteorologic de Catalunya in W/m^2. The meteorological station is placed in Sant Pere
251 de Ribes, 6 km away from OBSEA.
252
253 Statistical analysis
254 A Canonical Correlation Analysis (CCA) was performed on the dataset. CCA is a
255 multivariate statistical model that facilitates the identification of interrelationships

256 among sets of multiple dependent variables with single or multiple independent
257 variables (Sherry & Henson, 2005). In our case, the correlation between the mobility of
258 each species (independent variable) and a set of independent variables was studied.
259 These set independent variables were: temperature (ºC), pressure (dBar), salinity (PSU),
260 water current speed (m/s) and direction (degrees in relation to North), and light
261 irradiance (W/m^2).
262
263 **Results**
264 Spiny lobsters (P) presented low activity patterns and mainly remained in the artificial
265 reef area where they were released (Fig. 3a; Table 1). Movements were realized at any
266 time of day-night cycle. The lobster released in the AR1 moved to the AR3 and its
267 activity was lost on the 28th of August 2011. The specimen released in the AR2
268 remained around this production module; however, recovery data was partially missing
269 between July 28th and August 31th. The lobster released in the AR3 moved around this
270 module, but stopped moving after the 28th of July. At the end of the study, when
271 SCUBA divers visited the study area, they found that this specimen was dead.
272 All spider crabs (M), showed a higher activity profile than the lobsters, either at
273 day or night. Spider crab activity was tracked for a maximum of 48h when the signal of
274 the transmitter was lost, because they were out of the area of reception of the
275 hydrophones (Fig. 3b; Table 1). The spider crab released in the AR1 moved South to
276 H4, then went back to North-East direction, turned to West and finally moved again to
277 the South. The spider crab released in the AR2 went to the East after being released and
278 then turned to the South. The spider crab released in the AR3 moved to the South and
279 left the artificial reef area in that direction.

No pattern was observed between the movements of the spiny lobsters and spider crabs and the following environmental parameters: salinity and pressure; although some animals presented significant differences that were not supported by other crabs or lobsters (Table 2). Temperature was positively correlated with movement of spider crabs, but no effect was observed in two lobsters while P3 presented a negative correlation (Table 2). Current speed and direction did not increase until 20 h after the animals were released. There was a trend, although not statistically significant, between the current speed and light intensity and the movement of the spider crab (M2) that presented the higher time of detection in the reef area. M3 moved first towards the North-West and when the speed of the current speed increased and its direction was from the North. Then M3 changed the direction of the movements towards the East. M2 also presented a correlation of its movement with the current speed, moving towards the South when the strongest current from North appeared. M1 moved first to the East, but then also exited the AR in the South direction (Table 2). As a general pattern when current speed was intense spider crabs moved against the current.

Discussion

Our pilot study suggests that the artificial reef areas might be good sites for stocking and conservation of adult *Palinurus mauritanicus*, but not for adults of *Maja squinado*, since our released males left their deployment areas in less than 48-h. This behaviour was correlated with different changes in some tested environmental parameters.

The two released spiny lobsters remained in the same module where they were initially placed by the SCUBA divers and the third one moved from the AR1 to the AR3 (114 m). In *J. lalandi* and *P. cygnus* it was observed significantly greater movements in the first two days following tagging and release although nomadic movements were

described for this species (Atkinson et al., 2005; MacArthur et al. 2008). In our study, the movement of *P. mauritanicus* ranges were limited, remaining most of the time inside the module confirming the sheltering life-habit observed in other areas (Latrouite et al., 1999). Tag-recapture studies conducted in the Atlantic Ocean and Mediterranean Sea with the closer spiny lobster species, *P. elephas*, indicated that adult movements are generally restricted (5 km in 8 years) and that they are primary active at night for foraging and reproduction (reviewed by Goñi & Latrouite, 2005). In the Mediterranean, slipper lobsters migrate into deeper water as the sea temperature rises in summer, but tagged individuals were seen to return to the reef over a 3 year period (Spanier et al., 1988). In our study, no correlation with light or any other environmental factors was found in *P. mauritanicus*, while Bertelsen (2013) probed that the percentage of lunar illumination triggers the restricted movement of large males of *P. argus*.

The site fidelity and the limited movements of palinurid lobsters directed fisheries management towards the use of marine reserves to protect lobster populations (Kelly et al., 2000, 2003) and restocking programs based on the release of wild specimens were carried out in Sardinia (Giacalone et al. 2006) and in southern Australia (MacArthur et al. 2008; McGarvey, 2004). Relatively small marine protected areas enhance *P. elephas* adult stock biomass in the Mediterranean (Goñi et al., 2001) and it is known that marine reserves are most effective in species of intermediate movements as *P. elephas*. Lobster and fish biomass export was observed in the vicinity of the reserve and extended as far as 2500 m (Goñi et al., 2008). The creation of spiny lobster fishing grounds through the utilization of concrete blocks began in 1933 and it has been proved that artificial reefs increased the yield of lobsters in Japan (Nonaka et al., 2000). Artificial reefs were also used to restock homarid lobster in United Kingdom (Jensen et al., 2000). The limited movements of *P. mauritanicus* observed in the present study and

330 the restriction of fishing in the artificial reefs induced us to propose the use of the infra-
331 utilized artificial reefs in the Catalan coast for re-stocking this lobster species.
332 The spider crab presented higher activity compared to the spiny lobster and we
333 were able to record their movements only between 21 and 45-h-post releasing. Their
334 movements were correlated with current speed and direction, as well as light intensity,
335 while no effect on their movement ranges was observed by changes in temperature and
336 salinity. Current speed increased 20-h after the releasing of crabs, when the movement
337 of individuals generally occurred against the water flow. Movements of the spider crabs
338 preferentially occurred during the daylight phase and increased with increasing
339 temperature. *M. squinado* migrate towards deeper zones in autumn and return to
340 shallower and nursery areas in spring, where juveniles stay (Bussani & Zuder, 1977;
341 Stevcic, 1967, 1973) but mark-recapture studies cannot provide a detailed description of
342 the adult movement nor of elicit environmental factors. *M. brachydactyla* presented a
343 similar migration pattern (Gonzalez-Gurriaran & Freire, 1994) and adults move out
344 from Spanish Atlantic fjords 3-fold faster than juveniles and sub-adults, with a positive
345 correlation with temperature, as we found here. Corgos et al. (2011) confirmed that
346 movement, observing also that all crabs recaptured on deep bottoms showed clear
347 directionality moving towards the North, while in autumn the main current is from the
348 South. Differences in movements between juveniles and adults were also observed in
349 the blue crab *C. sapidus*, only adults moved directional into the main stem of
350 Chesapeake Bay with a speed more than twice those of juveniles (Hines et al., 1995).
351 While *M. brachydactyla* and *C. sapidus* did no present different behavior in their
352 movement patterns between sexes (Hines et al., 1995), females of *C. pagurus* migrated
353 significant longer distances with a net southern direction and males stayed within the
354 area of release with short movements also directional (Ungfors et al., 2007). A two

355 month acoustic transmitter experiment realized by the former authors with nine crab
356 males showed a varied individual pattern: some individuals stayed in the same area for
357 weeks, whereas some made regular movements every day during the tracking period.
358 Although the movements were correlated with temperature in *M. squinado* from
359 the present study no correlations were observed with this environmental factor and other
360 in another crab species (Guerra-Castro et al., 2007). In contrast to palinurid lobsters,
361 crabs realized migrations as adults (present study, André et al., 2012; Hines et al., 1995;
362 Ungofors et al., 2007) and present a short ontogenic development (cf. Guerao et al.,
363 2008; Johnson et al., 2011, Ut et al., 2007). Over the last decade, this short development
364 in comparison to spiny lobsters (Nonaka et al., 2000), allowed researcher technically
365 and economically feasible hatchery production of juvenile crabs as the mud crab *Scylla*
366 spp. (Lebata et al., 2009; Le Vay et al., 2008; Ut et al., 2007), the swimming crab
367 *Portunus trituberculatus* (Miers, 1876) (Okamoto et al., 2004) and the blue crab *C.*
368 *sapidus* (Davis et al., 2004, 2005a, b; Johnson et al., 2011) with a net increase in
369 fisheries' yield. Therefore, re-stocking programs in crabs has been based in the release
370 of juveniles instead of adults, although has stated by Lebata et al. (2009) there is a need
371 for species and site-specific studies. During the three years re-stocking Spanish project
372 REPES we developed hatchery technology to grow up larvae and juvenile of the spider
373 crab *M. squinado* (Durán et al., 2012; Guerao et al., 2008; Guerao & Rotllant, 2010;
374 Rotllant et al., 2014) however we do not reach enough mass production to be able to
375 release juveniles. As stated by Corgos et al. (2011), juveniles of the sibling species *M.*
376 *brachydactyla* are nomadic and therefore we suggest that the realease of juveniles of *M.*
377 *squinado* in the artifical reef could be a proper restocking technique in the
378 Mediterranean for this species overfished and strictily protected (Abad, 2003;
379 Anonymous 1999).

In conclusion, the present pilot study has proved the effectiveness of acoustic tracking for adult male lobsters and crabs in a well dispersed reef environment. Our piloting results suggest that male lobsters remain, for a short summer period, within the reef structures. This highlights the potential for lobster restocking of artificial reefs. Males of spider crab did not stay in the reef area, but from former studies we can suggest that the AR could be a potential releasing area for juveniles up to newly mature adults (1-3 months after terminal molt). Finally, current speed and direction, light and temperature were environmental factors triggering the movements of the spider crabs. Current direction was the main factor for spider crab movements and the spider crab direction was against current when speed current was intense.

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624

625 **Figure Captions**

626 **Fig. 1** Map showing the location of the coastal Seafloor Observatory (OBSEA), where the
627 artificial reefs (AR) are situated.

628 **Fig. 2** Schematic representation of the artificial reefs (AR) close to the coastal Seafloor
629 Observatory (OBSEA). VEMCO Ltd VR2W Coded Acoustic Hydrophones (H1, H2
630 and H3) were situated in the middle of each reef module and a fourth one (H4) in the
631 geographic centre among the three AR where the other H were located.

632 **Fig. 3** Movement ranges of spiny lobsters *Palinurus mauritanicus* (a) and spider crabs
633 *Maja squinado* (b) in the reception area of the hydrophones located in the artificial reefs. P:
634 spiny lobster; M: spider crab.

Figure
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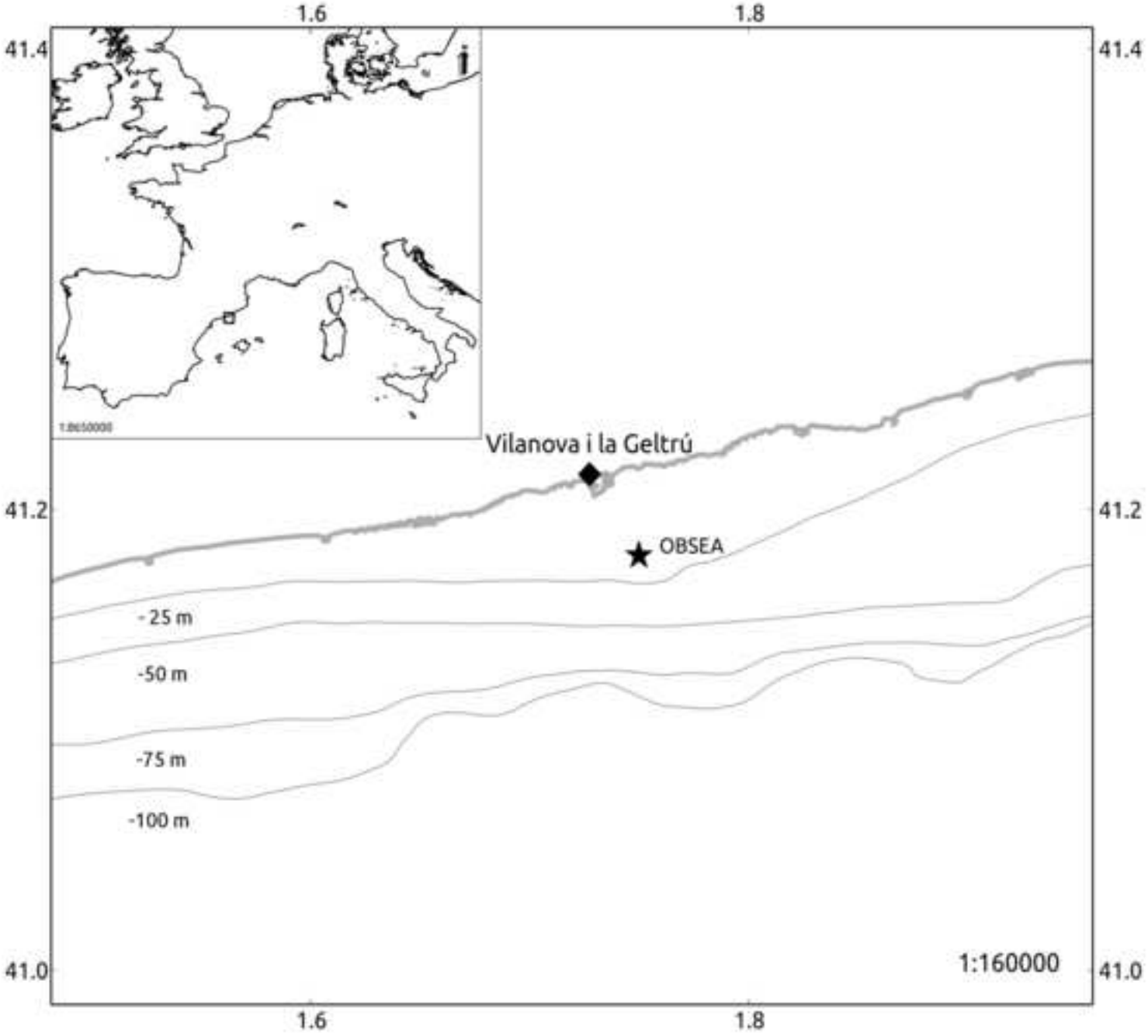

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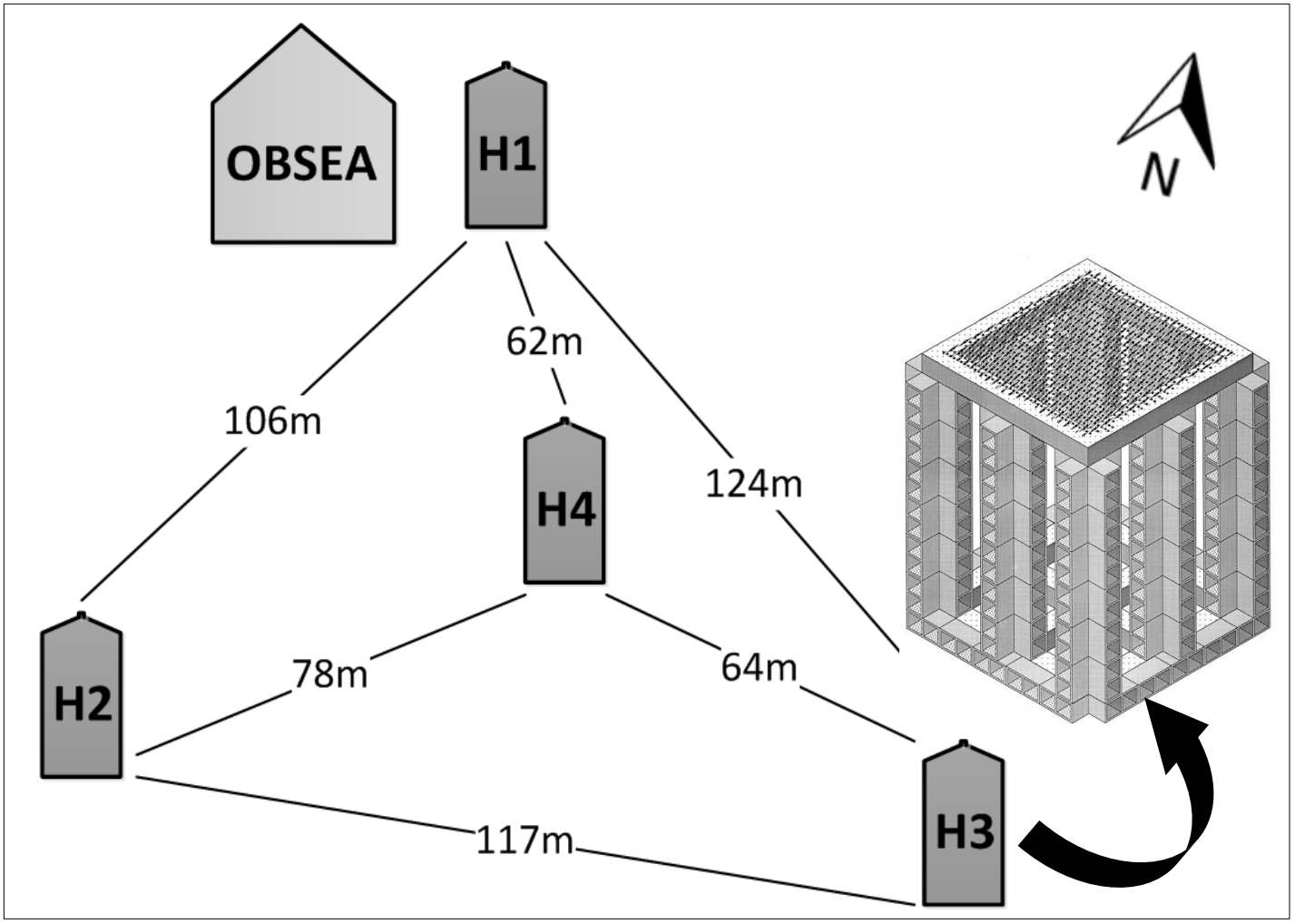

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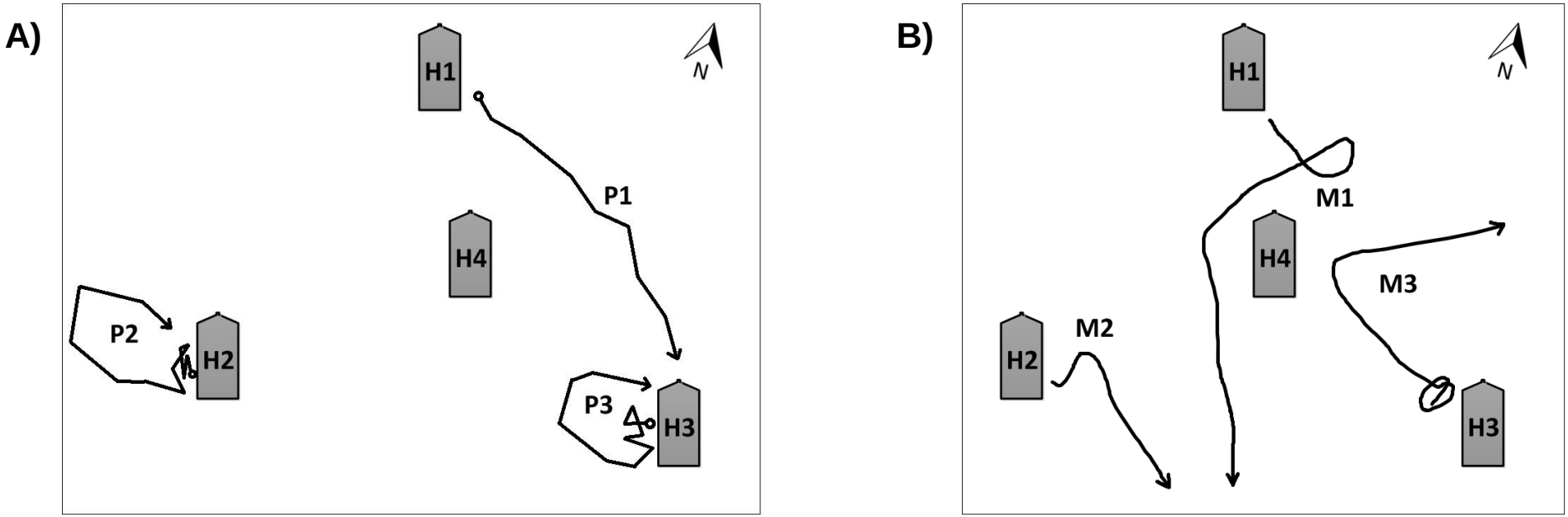

Table

Table 1. Identification of transmetters and durantion of the reception of the sound per species.

Species	No. Transmitter	Animal code	Artificial reef of release	Sound reception (days)	Total movement (m)	Mean rate of movement (m d^{-1})	Track spot points
Palinurus maritanicus	772	P1	AR1	41	114	2.78	148680
	771	P2	AR2	10+20*	80**	2.67	60856
	770	P3	AR3	10	40**	4	14028
				(h)			
Maja squinado	767	M1	AR1	21	140	160	1858
	768	M2	AR2	45	90	48	243
	764	M3	AR3	26	118	108.92	3395

No clear signal received between 28/7/2011 and 31/8/2011

** Imprecise due no clear signal between hydrophones

Table
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Table 2. Probability (P<0.001) between movement of the crustaceans and environmental parameters.

Species	Animal code	Temperature (ºC)	Pressure (dBar)	Salinity (PSU)	Current Speed (m s^{-1})	Current direction (degrees)	Light Intensity (W m^{-2})
Palinurus maritanicus	P1	-0,1045	-0,21959*	-0,061604	-0,15251	-0,097988	0,13373
	P2	0,1791	0,24529*	0,29209*	0,16844	-0,031496	-0,040897
	P3	-0,25282*	-0,02879	-0,21139*	0,099221	0,14371	0,036754
Maja squinado	M1	0,3096*	-0,15889	0,50736*	0,16683	-0,01431	0,11386
	M2	0,29567*	-0,1548	0,15732	0,050236	0,25071*	0,42594*
	M3	0,26404*	-0,39998*	0,075104	0,29035*	-0,1535	0,095226

*Significant differences.

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